

# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



### THESIS

**SCHEDULING AIRCREW TRAINING AT UNITED  
STATES NAVY FLEET READINESS SQUADRON HC-3  
DURING REPLACEMENTS OF H-46D HELICOPTERS BY  
CH-60S**

by

Kevin S. Jasperson

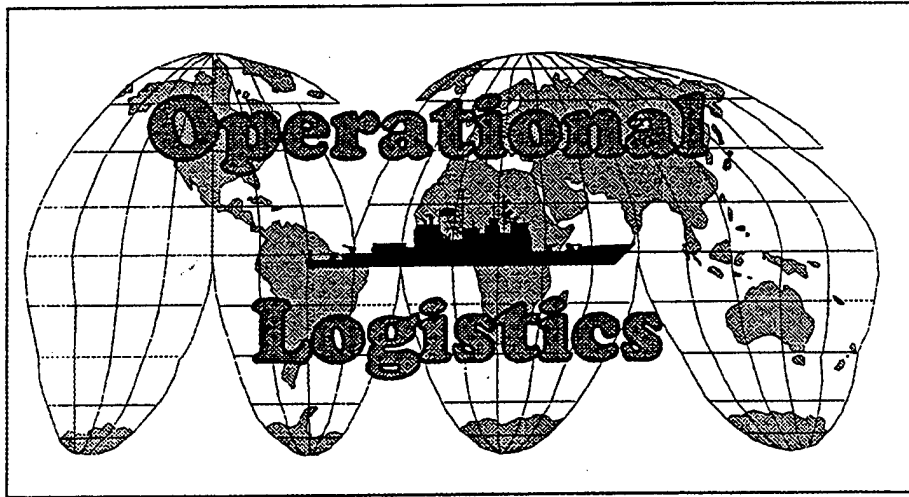
September 1999

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*Amateurs discuss strategy,  
Professionals study logistics*



# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE September 1999	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE SCHEDULING AIRCREW TRAINING AT UNITED STATES NAVY FLEET READINESS SQUADRON HC-3 DURING REPLACEMENTS OF H-46D HELICOPTERS BY CH-60S		5. FUNDING NUMBERS	
6. AUTHOR(S) Jasperson, Kevin S.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) H-60R/S Fleet Introduction Team, CNAP (N8H) P.O. Box 357123 San Diego, CA.		10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The United States Navy is replacing the H-46D helicopter with the new CH-60S helicopter. Helicopter Combat Support Squadron Three (HC-3) is the U.S. Navy's Fleet Readiness Squadron, responsible for training the contingent of pilots and aircrewmembers to fly this helicopter fleet; it is also responsible for managing their transition to the CH-60S. Each pilot and aircrewman represents a large investment in training and experience, and each is engaged in some stage of a Navy career that is governed by a host of guidelines for training, service experience, sea and shore duty rotations, and so forth. This thesis introduces an optimization model that takes as input the current state of Navy pilots and aircrewmembers, the schedule of CH-60S introductions, restrictions on career duty tours and qualifying experience, limits on training resources, and other policy guidelines. The output is a schedule of duty tours, including training, retraining, shore, and sea duty tours, while recommending an optimal set of career paths to accommodate the transition over an 84-month period.			
14. SUBJECT TERMS Training, Aviation, Optimization, Modeling, Logistics		15. NUMBER OF PAGES 66	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)  
Prescribed by ANSI Std. Z39.18



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READINESS SQUADRON HC-3 DURING REPLACEMENTS OF H-46D  
HELICOPTERS BY CH-60S**

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Submitted in partial fulfillment of the  
requirements for the degree of

**MASTER OF SCIENCE IN OPERATIONS RESEARCH**

from the

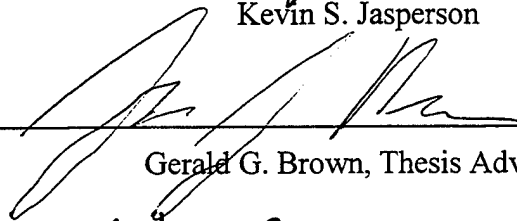
**NAVAL POSTGRADUATE SCHOOL  
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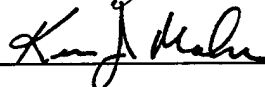


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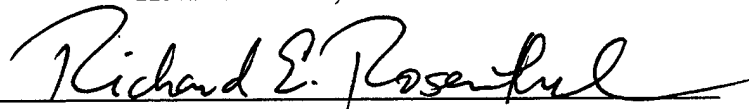
Approved by:



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Department of Operations Research



## ABSTRACT

The United States Navy is replacing the H-46D helicopter with the new CH-60S helicopter. Helicopter Combat Support Squadron Three (HC-3) is the U.S. Navy's Fleet Readiness Squadron, responsible for training the contingent of pilots and aircrewmen to fly this helicopter fleet; it is also responsible for managing their transition to the CH-60S. Each pilot and aircrewman represents a large investment in training and experience, and each is engaged in some stage of a Navy career that is governed by a host of guidelines for training, service experience, sea and shore duty rotations, and so forth. This thesis introduces an optimization model that takes as input the current state of Navy pilots and aircrewmen, the schedule of CH-60S introductions, restrictions on career duty tours and qualifying experience, limits on training resources, and other policy guidelines. The output is a schedule of duty tours, including training, retraining, shore, and sea duty tours, while recommending an optimal set of career paths to accommodate the transition over an 84-month period.

## **DISCLAIMER**

The reader is cautioned that computer programs developed in this research may not have been tested for all possible cases. While every effort is made to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional validation is at the risk of the user.



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## LIST OF ACRONYMS AND ABBREVIATIONS

BUPERS	Bureau of Naval Personnel
CH-60S	Cargo Helicopter, model 60, series S
CO	Commanding Officer
CPLEX	Commercial Optimization Software
CTM	Crewmen Training Model
EDVR	Enlisted Data Verification Record
FIT	Fleet Introduction Team
FRS	Fleet Readiness Squadron
GAMS	General Algebraic Modeling System
H-46D	Helicopter, model 46, series D
H-60R/S	Helicopter, model 60, series R and S
HC	Helicopter Combat Support Squadron
Helsuppron	Helicopter Combat Support Squadron
IUT	Instructor Under Training
NAS	Naval Air Station
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
NPC	Naval Personnel Command/ BUPERS
ODCR	Officer Distribution Control Report
OPNAVINST	Operational Navy Instruction
PMA	Program Management Analysis (Multi-Mission Helicopter Program Office)
PERS	Naval Personnel Command/ BUPERS
SAR	Search and Rescue
VERTREP	Vertical Replenishment
VX	Experimental Aircraft Test and Evaluation Squadron
XO	Executive Officer





## EXECUTIVE SUMMARY

The U.S. Navy is replacing the H-46D helicopter that has been its primary vertical replenishment aircraft for four decades. Age, increased maintenance costs, and lower aircraft availability are the primary motives. The replacement helicopter is the CH-60S, designed, produced, and delivered by the Sikorsky Aircraft Corporation. The CH-60S is expected to perform vertical replenishment, search and rescue, vertical on-board delivery, and airhead operations with 80% fewer mission aborts, 56% fewer component removals, and 58% fewer unscheduled maintenance actions than the H-46D.

The replacement program is outlined in the Helicopter Master Plan and is administered by the H-60R/S Fleet Introduction Team (H-60R/S FIT) at NAS North Island, California. Helicopters are scheduled to be replaced on a one-for-one basis until the last replacement occurs in about seven years.

Helicopter Combat Support Squadron Three (HC-3) is the U.S. Navy's Fleet Readiness Squadron, responsible for training pilots and aircrewmen to fly HC helicopters. HC-3 has been designated to train all pilots and aircrewmen for both aircraft throughout the transition.

HC-3 and the H-60R/S FIT must determine by aircraft type and category the number of crewmen to train to meet fleet squadron manning requirements to support both types of aircraft during this transition. The numbers are taken from a population composed of new flight school crewmen and experienced fleet crewmen, where each experienced crewman is engaged in a duty tour at some stage of his or her naval career and eligible for training and a follow-on tour.

The objective of this thesis is to help HC-3 and the H-60R/S FIT determine the rate at which and method with which training should be conducted at HC-3 to ensure that crewmen manning requirements at HC-2, HC-3, HC-5, HC-6, HC-8, and HC-11 are met throughout the transition from the H-46D to the CH-60S helicopter. During this time, the fleet squadrons must be able to meet their logistical support requirements to the Navy's battle groups and amphibious ready groups.

Data for this thesis was manually collected from all of the HC squadrons, the Naval Air Systems Command, and the Naval Personnel Command. This data was then transformed into a format for use in an optimization model.

The model forecasts squadron manning requirements and determines the optimal types of pilots and aircrewmen and class size of each type of pilot and aircrewman to start training at the beginning of each month of a calendar year. Classes are drawn from pilots and aircrewmen completing a prior duty tour or flight school during the prior month. The model takes into account the CH-60S and H-46D phased distribution schedule and the limited availability and utilization of training aircraft at HC-3. It takes into account the limited availability of HC-3 pilot and aircrewmen instructors and the training and phasing of the instructor population in concert with the change in aircraft at HC-3. The model accounts for HC-3 student class size restrictions, available pilots and aircrewmen to enroll in these classes, pilot and aircrewmen career cycle rotation and duty tour lengths including shore duty and disassociated sea tours. The model also considers the professional experience of each officer and enlisted member, the number of enlisted and officer billets in all of the subject HC squadrons, and the primary roles of officers at HC

squadrons. The model considers flight hour limitations induced by budget, aircraft, instructors, and students. The model also includes two special groups of crewmen that must be trained before the beginning of the transition. The first is composed of the ten CH-60S cadre pilots and eight cadre aircrewmen. The second is composed of the 18 detachment pilots for the earliest fleet CH-60S HC detachments at HC-5 and HC-6.

The model characterizes a crewman's career by a succession of career cycles. Each career cycle begins with a training syllabus to become qualified for a follow-on tour of duty at an HC squadron, and ends with the expiration of that duty tour. Shore duty or disassociated sea duty at a command outside of the HC community also constitutes a career cycle. Career cycle pairings within the model ensure an appropriate crewman fills career cycles that require certain credentials and experience. For example, to be assigned as an instructor at HC-3, the crewman must be transferring from an HC squadron tour. By contrast, a first-tour pilot is not allowed to become an executive officer of a squadron. Career cycles last between 24 and 47 months, with duration determined by the Bureau of Personnel according to billet type and crew qualification.

The model suggests a feasible monthly training schedule for all categories of pilots and aircrewmen that optimizes the utilization of HC-3 aircraft and manpower resources to fill the minimum crewmen manning requirements for aircraft within squadron billet limitations. This model does not place crewmen at their respective squadrons, but it does ensure that there are enough pilots and aircrewmen to fill minimum aircraft crewmen requirements, executive officer and commanding officer requirements, and HC-3 pilot instructor requirements. This model does not predict squadron

department head requirements, but does use prior fleet-experienced pilots for retraining for department head tours and super-junior officer tours.

The H-60R/S FIT already has a spreadsheet that prescribes a training schedule. The goal of this thesis is to verify, validate, and reconcile any undiscovered errors or oversights in the (undocumented) spreadsheet. The H-60R/S FIT wants this formal optimization model to validate their spreadsheet.

The results of the thesis evaluate the sufficiency of the HC-3 training aircraft population, instructor endowment, and flight hour budget. This provides insight into the feasibility of the Sikorsky CH-60S distribution schedule and the H-46D retirement plan.

Summary results for the 18 May 1999 CH-60S distribution schedule are:

1. There will be sufficient training aircraft throughout the transition.
2. A planned budget of 1,575 flight-training hours per quarter is adequate.
3. There will be a shortfall of H-46D instructors during the first year of the transition if the current deficiency of H-46D crewmen is to be corrected.
4. There should not be any other resource shortfalls during the transition.

Because a feasible training schedule can be achieved that satisfies all H-46D and CH-60S manning requirements and does not cause any significant resource shortfalls in HC-3, there are three recommendations:

1. HC-3 maintain its current training and operating structure.
2. H-60R/S FIT maintain its planned operation and training structure for HC-3.
3. H-60R/S FIT use its spreadsheet-scheduling model in its current form.

## ACKNOWLEDGMENT

I would like to thank the H-60R/S Fleet Introduction Team and CAPT. John Mullarky for sponsoring and supporting this thesis.

My sincere appreciation goes to the enlisted and officer detailers at Naval Personnel Command for their help in collating the historical data required for this thesis.

I would like to express my deepest appreciation to Professor Gerald Brown for his enduring patience and guidance towards the development and successful completion of this thesis.

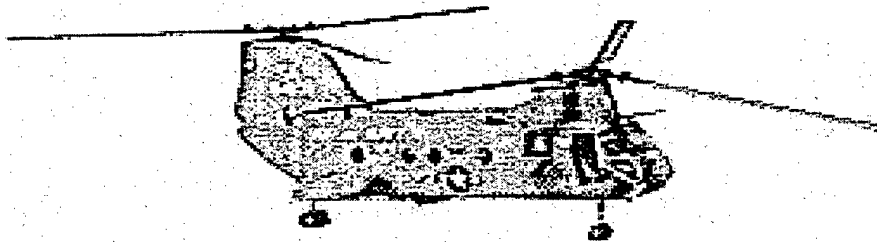
I would also like to thank my wife, Jocelyn, for her love and patience, without which this endeavor would not have been possible.



## I. INTRODUCTION

### A. BACKGROUND

The Boeing H-46D Helicopter (Figure 1) has been the primary vertical replenishment (VERTREP) support aircraft for the US Navy for four decades. Initial deliveries were taken from Boeing Aircraft Corporation in June 1964, while some were transferred from the Marine Corps in the 1970's after the Vietnam War. As of June 1998,



**Figure 1. The H-46D Sea Knight Tandem Rotor Helicopter**

The H-46D Sea Knight tandem rotor helicopter is used by the U.S. Navy, Marine Corps, and by various countries. It has been serving customers around the world for more than 40 years. The U.S. Navy uses 73 H-46D aircraft in missions of vertical replenishment, vertical on-board delivery, search and rescue, medical evacuation, combat support, special warfare and general utility. Other countries flying the Sea Knight include Canada, Sweden, Japan, and Saudi Arabia.

there were 73 H-46D aircraft in the U. S. Navy inventory. Of these aircraft, 57 have exceeded their 10,000 hour projected service life span [NAVAIR, 1998a].

The H-46D is a twin rotor, dual engine, multipurpose aircraft. Its maximum forward airspeed is 145 knots, although it is limited to 35 knots sideward flight and 30 knots rearward flight. Its maximum gross weight is 23,000 pounds. It has an external lift capability of 6,000 pounds or an internal lift capability of approximately 3,600 pounds. The cabin has provisions for accommodating 25 troops or 15 litters. It has all weather,

day and night capabilities for vertical replenishment and search and rescue (SAR) [NATOPS, 1996].

The H-46D has undergone numerous airframe alterations to improve its operational capabilities, extend its life span, and correct material and maintenance deficiencies in an effort to prevent aircraft mishaps due to structural failure. The safety, reliability and maintainability modification kit program of the late 1980s provided a fully modernized H-46 fleet that could operate economically through the 1990s. Contract upgrades provided through Boeing from calendar year 1990 through 2000 include an emergency-flotation system, an engine condition control system kit, a night-vision goggle kit, and a dynamic component upgrade kit that replaces all drive train and rotating parts with new and refurbished parts.

Increased maintenance costs and lower aircraft availability rates have led the Department of the Navy to replace the H-46D fleet with a completely different airframe. The replacement aircraft, the CH-60S, is developed by the Sikorsky Aircraft Corporation, and will replace the entire H-46D fleet by the year 2005.

The CH-60S operates with a standard crew of four, composed of one pilot, one co-pilot, and two enlisted aircrewmen (the number of aircrewmen will vary with the type of mission). This helicopter is completely compatible with all current and future Aircraft Carriers, Combat Logistics Force ships, Military Sealift Command ships and Amphibious Task Force ships without any major ship alterations. Based on data collected from U.S. Navy SH-60 squadrons, the CH-60S has lower maintenance costs, and its cost per flight hour is less than half of the H-46D. Sikorsky projects 80% fewer mission aborts, 56%



fewer component removals, and 58% fewer unscheduled maintenance actions compared with the H-46D [SIKORSKY, 1999]. A picture of the CH-60S prototype appears in figure 2.



**Figure 2. CH-60S Prototype**

This is a photo of the prototype CH-60S performing VERTREP. The CH-60S is derived from the Army UH-60 Blackhawk utility airframe in combination with the Navy SH/HH-60 transmission and dynamic components. The CH-60S will be able to carry up to 13 passengers or two 40 x 48 x 40-in. Navy triwall pallets, weighing a total of up to 4,000 lbs. It will be able to lift up to 9,000 lbs. on an external hook while flying sideways at 45 knots, or backwards at 40 knots. It will be able to operate day or night, under adverse weather conditions, including flight in light icing [SIKORSKY, 1999].

The primary missions of the CH-60S are day and night VERTREP, day and night Amphibious Search and Rescue, Vertical Onboard Delivery, and airhead operations.

Secondary missions include Medical Evacuation, Non-combatant Evacuation Operations, Combat Search and Rescue, Special Warfare Support, Airborne Mine Countermeasures, humanitarian assistance, personnel transport, disaster relief, and recovery of torpedoes,

drones, and unmanned aerial and underwater vehicles. The CH-60S Integrated Test Team, composed of Sikorsky and U.S. Navy Test and Evaluation personnel, completed a successful Developmental and Operational Assessment of a prototype CH-60S during the first quarter Fiscal Year 1998. Developmental and Operational Testing of production aircraft is scheduled to begin the second quarter of Fiscal Year 2000 by a team composed of personnel from Sikorsky, U.S. Navy Test and Evaluation, and VX-1, the U.S. Navy's experimental aircraft test squadron located at Naval Air Station (NAS) Patuxent River, Maryland.

#### **B. H-46D REPLACEMENT PROGRAM**

The Helicopter Master Plan [NAVAIR, 1998b] delineates the replacement of U.S. Navy H-46D helicopters with the CH-60S helicopter. The procurement and notional delivery schedule for the CH-60S indicates the first aircraft deliveries from Sikorsky will be made to Helicopter Combat Support Squadron Three (HC-3) in the fourth quarter of Calendar Year 2000. The last H-46D will be replaced no later than the end of Calendar Year 2006. HC-3 is the U.S. Navy's H-46D and CH-60S Fleet Replacement Squadron (FRS). HC-3 provides training to pilots and aircrewmembers to fly the H-46D helicopter.

To administer the plan, the H-60R/S Fleet Introduction Team (FIT) has been established at NAS North Island, San Diego CA under Commander Naval Air Forces Pacific. The primary purpose of the H-60R/S FIT is to function as the single point of contact for the CH-60S fleet introduction. The H-60R/S FIT coordinates fleet inputs and provides guidance to CH-60S program offices, the Naval Air Training and Operating

Procedures Standardization (NATOPS) Model Manager, the FRS Curriculum Model Manager, and the fleet H-46D and CH-60S maintenance, supply, and training programs.

Pilots and aircrewmembers are trained to fly either the H-46D or the CH-60S. For a minimum of 3.5 calendar years, HC-3 will be concurrently training H-46D pilots and aircrewmembers, and CH-60S pilots and aircrewmembers. This training includes classroom lectures in aviation rules, safety, tactics, and maintenance. It entails aircraft inspections and flying training sorties, while learning basic flight, navigation, SAR, and VERTREP techniques.

As one CH-60S enters the fleet, one H-46D is retired. In anticipation of CH-60S deliveries to HC-3 and the five other fleet squadrons, HC-3 must determine the number of pilots, aircrewmembers, and flight hours needed to support these aircraft at minimal operational cost, per given time period. From these numbers HC-3 must determine by aircraft type and category, the number of pilots and aircrewmembers to be trained to meet fleet squadron manning requirements; they also must forecast the number of flight hours needed to support these requirements. Table 1 shows a plausible outline to the training solution.

Type Aircrew	Category (Index)	Syllabus Length Days	Class Size	Start Syllabus Date	Graduation Date	Date Required at Squadron (s)
H-46D Pilot	1	150	10	01 May 2001	01 Oct 2001	15 Oct 2001
H-46D Pilot	2	100	4	05 Jun 2001	01 Oct 2001	15 Oct 2001
CH-60S Pilot	5	122	5	01 May 2001	01 Sept 2001	15 Sept 2001
CH-60S Pilot	IUT	52	2	15 Jun 2001	01 Aug 2001	01 Aug 2001
H-46D acrw	3	84	6	01 Jul 2001	01 Sept 2001	15 Sept 2001
CH-60S acrw	1	120	10	01 Jun 2001	01 Oct 2001	15 Oct 2001

**Table 1. Aircrew Class Requirements for H-46D Replacement by the CH-60S**

This table illustrates a plausible outline of a solution given by an H-46D Fleet Replacement program. For example, if fleet squadron requirements dictate a need for ten H-46D category-one pilots and ten CH-60S category-one aircrewmembers by 15 October 2001, then HC-3 would have to start training ten new pilots no later than 01 May 2001, start training ten new aircrewmembers no later than 01 June 2001.

Meeting these requirements is important in that it is necessary throughout this transitional period that the HC squadrons be fully capable of meeting their operational obligations of logistical support to the fleet battle groups and amphibious ready groups as well as homeport mission duties. This implies the squadrons will be managing and maintaining two different types of aircraft simultaneously and keeping both in a high state of readiness. This will require that the squadrons maintain high aviation safety standards, flexibility, and highly trained personnel. The projected delivery schedule for each of the HC squadrons is listed in Table 2.

CALENDAR YEAR	00	01	02	03	04	05	06	07	TOTAL
<b>SQUADRON:</b>									
HC-3	7	3	4	3	0	0	0	0	17
HC-5	0	7	7	0	0	0	0	0	14
HC-6	0	8	4	4	0	0	0	0	16
HC-8	0	0	0	6	6	4	0	0	16
HC-11	0	0	0	7	10	6	0	0	23
HC-2	0	0	0	0	0	3	6	2	11

**Table 2. Squadron Delivery Schedule**

This table shows the current delivery schedule of CH-60S aircraft to the six helicopter combat support squadrons listed on the left, per year, from the year 2000 through the year 2007.

The purpose of this thesis is to implement a pilot and aircrewmen fleet replacement program that will provide HC-3 and the H-60R/S FIT a feasible mix of pilots and aircrewmen to train, while meeting the projected manning requirements for predetermined numbers of H-46D and CH-60S aircraft for all time periods throughout the transition. The problem lies in the fact that there will be nineteen different training cycles for CH-60S and H-46D aircraft to train nine categories of pilots and aircrewmen. Any one category of pilot or aircrewmen requires a special training cycle depending on the

student's experience and prior tour of duty. The training cycles vary in duration and require different amounts of flight time. The number of training cycles will shrink to eleven when all H-46D aircraft have been retired from the fleet.

The H-60R/S FIT will oversee the flow of pilots and aircrewmembers into the HC-3 training pipeline. Training cycle lengths have been determined for all categories of personnel. The training syllabus lengths for all CH-60S categories of pilots and aircrewmembers are shown in Table 3. A training syllabus consists of all classroom and flight requirements to become qualified in the H-46D or CH-60S.

Category	Syllabus (days)
Cat 1 Pilot (First tour in model )	150
Cat 2 Pilot (Second tour in model)	100
Cat 3 Pilot (XO/CO, experienced in model)	73
Cat 4 Pilot (Special, SAR/Utility/Air Station crews)	87
Cat 5 Pilot (Transition from other helicopter model, i.e. H46)	122
Instructor under training (IUT) Pilot	52
Cat 1 Aircrew (First tour in model)	120
Cat 2 Aircrew (Second tour in model)	56
Cat 3 Aircrew (Transition from other helicopter model)	84
Cat 4 Aircrew (Special, SAR/Utility/Air Station crews)	30
IUT Aircrew	35

**Table 3. CH-60S Training Syllabus Durations**

This table shows the number of days to train a specific type of pilot or aircrewmembers in the CH-60S helicopter. For example, a pilot with previous H-46D experience who is transitioning to the CH-60S, would be in Category 5 training and would require approximately 122 days to complete the syllabus and be qualified "in model". Qualified "in model" refers to a pilot or aircrewmembers satisfactorily completing all phases of the syllabus. A Category 4 pilot receives training in a specific specialty such as Search and Rescue.

The number of personnel that can be trained per time period is limited by the availability of training aircraft, instructors, training tempo, and flight hour funding.

Currently, there are 30 H-46D pilot instructors, 14 aircrew instructors, and 14 H-46D aircraft at HC-3. During the transition, there will be a maximum of 30 pilot instructors,

24 aircrew instructors, and 17 combined H-46D and CH-60S training aircraft available for training. Instructors will be qualified to instruct in only one of the two types of aircraft. The ratio of CH-60S instructors to H-46D instructors will vary commensurate with the ratio of H-46D to CH-60S aircraft.

There are other constraints. As aircraft are delivered to the fleet, there must be available personnel within the fleet squadrons to support and fly them. There must not be a loss in squadron mission capability, and there must not be any growth in squadron manpower, except for unavoidable surpluses of newly trained personnel arriving from HC-3. Each HC squadron needs a certain number of each category of pilot and aircrewmen depending on the number and type of aircraft owned by the squadron for any time period. It is not practical to flood each squadron with trained personnel and have them wait an extended amount of time for aircraft to arrive. Each squadron has billeting constraints, and the normal rotation of personnel entering and leaving the squadrons must be maintained.

Aircraft deliveries from Sikorsky are the main motive of this problem. At this time, notional CH-60S and H-46D populations have been predetermined for HC-2, HC-3, HC-5, HC-6, HC-8, and HC-11. (e.g., Table 2 and Table 4)

HC squadrons send detachments to sea on Navy supply ships to primarily support underway replenishment. Normally, H-46D detachments deploy with two aircraft, six pilots, and eighteen maintenance personnel including six aircrewmen.

<b>Squadron</b>	<b>MO-YR</b>	<b>MO-YR</b>	<b>MO-YR</b>	<b>MO-YR</b>	<b>MO-YR</b>	<b>MO-YR</b>
<b>HC-3</b>	Jul-00	Aug-00	Sept-00	Oct-00	Nov-00	Dec-00
<b># of CH-60S</b>	0	0	3	5	6	7
<b># of H-46D</b>	14	14	11	9	8	7
<b>HC-5</b>	Aug-01	Sept-01	Oct-01	Nov-01	Dec-01	Jan-02
<b># of CH-60S</b>	5	5	5	5	5	7
<b># of H-46D</b>	9	9	9	9	9	7
<b>HC-6</b>	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01
<b># of CH-60S</b>	0	2	4	6	8	8
<b># of H-46D</b>	14	14	12	10	8	8

**Table 4. Squadron Aircraft Populations**

This table displays a six-month forecast of helicopter inventories for three of the squadrons undertaking the H-46D to CH-60S transition, with the number of CH-60S and H-46D aircraft each squadron should have during each month.

CH-60S detachments will also deploy with two aircraft, six pilots, but with only fifteen maintenance personnel including six aircrewmen. Pilot and aircrew requirements for HC detachments are determined from crew seat ratios. The crew seat ratio is the number of pilots or aircrewmen per seat per aircraft. The number of seats per aircraft is usually set to two (for the number of seats in the cockpit), and there are usually two aircraft in a detachment. If the ratio is 1.5 and there are four seats to multiply by, then the requirement will be for six pilots and six aircrewmen. The number of CH-60S detachments each squadron will field is currently undetermined.

This data comes from (1) current manpower documents; (2) aircraft procurement and deactivation documents; and (3) schedules. These include HC-3's Required Operational Capabilities and Projected Operational Environment document [OPNAV, 1998], and Weapon System Planning Data Procurement documents [NAVAIR, 1998c].

### **C. THESIS OBJECTIVE**

The objective of the thesis will be to assist HC-3 and the H-60R/S FIT in determining, with monthly precision, the rate at which and the method with which pilot and aircrew training should be conducted at HC-3 to adapt to the phased replacement of the H-46D aircraft. The focus will be on HC-3 training, rather than on personnel location (i.e., planning training, rather than determining squadron assignments).

Questions that motivate this thesis include:

1. At what time does a training system have to be in place?
2. What capacity does this system need to support?
3. How much additional funding is required for permanent changes of station, temporary duty under instruction, and operational tasking requirements to support the transition? When is this funding required?
4. What will be the replacement pilot load plan for each fiscal year?

The answers to these questions are important to facilitate the three necessary considerations when operating under tight budget constraints and high operation tempos. These considerations are fiscal planning, manpower management for the HC community, and long-range deployment scheduling.

This thesis supports significant changes in the HC community. Most important are aircraft safety, squadron depth of personnel, and flexibility.



## II. FORMULATION

The introduction of CH-60S aircraft and retirement of H-46D aircraft from the HC squadrons presents the problem of scheduling training for the different categories of pilots and aircrewmen, referred to herein as crewmen. The following mathematical formulation of the Crewmen Training Model (CTM) prescribes a schedule for training at HC-3. The reader may want to skip this section and refer back to it for clarification.

### A. FORMULATION

#### 1. Indices

$a$	aircraft qualification {H46D, CH60S, navhelo, nugget} (A 'navhelo' is already helicopter-qualified, but not in H46D or CH60S.) (A nugget is a new pilot out of flight school.)
$\tilde{a}$	subset of $a$ qualified to fly {H46D, CH60S}
$b$	billet type {pilot, aircrewman}
$r$	role {cadre, flying, instructor, XO/CO, expert, desk}
$\tilde{r}$	subset of $r$ with just flying roles {cadre, flying, instructor, XO/CO, expert}
$\tilde{\tilde{r}}$	subset of $\tilde{r}$ with just flying roles that train at HC3 {flying, instructor, XO/CO}
$r$	alias of $r$ .
$c, \bar{c}$	career cycle (i.e., enter with qualification $a$ and leave with $\tilde{a}$ , to fill billet $b$ , role $r$ )
$\bar{c}$	career cycle requiring flight training for $\tilde{a}$ (i.e., starts with a training tour, ends with a duty tour)
$s$	squadron {HC2, HC5, HC6, HC8, HC11, HC3}
$\bar{s}$	subset of $s$ excluding training squadron HC3
$p, \rho$	period ordinal (i.e., 1, 2, ...)
$ph$	alias for $p$ , historical planning period (i.e., before start of planning horizon.)
$pp$	alias for $p$ , planning period
$qp$	planning quarter

#### 2. Index Maps

$c(a, \tilde{a}, b, r)$	career cycle $c$ starts with qualification $a$ , ends with $\tilde{a}$ , filling billet type $b$ , role $r$
$\overline{pp}(qp), \overline{pp}(qp)$	first, last planning period in planning quarter $qp$

### 3. Index Sets

$\{c\}_{b,r,r}$	cycles $c$ with billet type $b$ and role $r$ that can immediately precede role $r$
$\{\bar{c}\}_{\bar{a},b,r}$	cycles $\bar{c}$ that train crewmen for aircraft type $\bar{a}$ , billet type $b$ , role $r$
$\{\bar{c}\}_{\bar{a},b,\bar{r}}$	cycles $\bar{c}$ that train crewmen for aircraft type $\bar{a}$ , billet type $b$ , role $\bar{r}$
$\{\bar{c}\}_{\bar{a},b,\bar{r}}$	cycles $\bar{c}$ that train crewmen for aircraft type $\bar{a}$ , billet type $b$ , role $\bar{r}$

### 4. Data

$\overline{enroll}_{\bar{c}}, \underline{enroll}_{\bar{c}}$	minimum, maximum size for cohorts in training career cycle $\bar{c}$ (crewmen)
$ttime_c$	time to train a crewmen for cycle $c$ (months)
$dtime_c$	duty tour length of cycle $c$ (months)
$sflthrs_{\bar{c}}$	syllabus training flight hours required for cycle $\bar{c}$ (hours)
$ratio_b$	crew seat ratio of billet type $b$ (crewmen/seat)
$helos_{\bar{a},s,pp}$	number of aircraft type $\bar{a}$ allocated to squadron $s$ during period $pp$ (aircraft)
$\overline{billets}_b$	maximum number of billets type $b$ (crewmen)
$stu2brd$	ratio of student pilots per aircraft at HC3 (crewmen/aircraft)
$stu2instr$	ratio of student pilots per instructor (crewmen/1)
$\overline{utilrate}_{\bar{a}}$	maximum flight hours per aircraft type $\bar{a}$ (hours/year)
$\overline{aflthrs}_{\bar{a},qp}$	maximum flight hours budgeted to HC3 by aircraft type $\bar{a}$ , in fiscal quarter $qp$ (hours/quarter)
$\overline{qlogtime}$	maximum hours an HC3 pilot instructor can fly (hours/quarter)
$\overline{mlogtime}$	maximum hours an HC3 pilot instructor can fly (hours/month)
$\overline{instructors}$	maximum instructors at HC3 (crewmen)
$\overline{roster}_{c,p}$	number of crewmen in training or on duty before planning horizon starts (crewmen)

### 5. Variables

$START_{\bar{c},pp}$	binary variable = 1 if a cohort of cycle $\bar{c}$ begins at start of period $pp$ ; = 0 otherwise
$EMPTY_{\bar{c},pp}$	positive variable; unused capacity in cycle $\bar{c}$ , period $pp$ (crewmen)
$COHORT_{c,p}$	integer variable; number of crewmen starting cycle $c$ at HC3, completing their first full period of training during period $p$ , graduating at the end of period $p + ttime_c - 1$ , serving a duty tour from $p + ttime_c$ through $p + ttime_c + dtime_c - 1$ (crewmen)

## 6. Formulation

Objective:

$$\begin{array}{c} \text{MINIMIZE} \\ \text{START, EMPTY, COHORT} \end{array} 0$$

We just seek any feasible solution to the following constraints.

Subject to:

$$COHORT_{\bar{c}, pp} + EMPTY_{\bar{c}, pp} = \overline{enroll}_{\bar{c}} * START_{\bar{c}, pp}, \quad \forall \bar{c}_{\bar{a}, b, \bar{r}}, pp \quad (1)$$

$$EMPTY_{\bar{c}, pp} = \overline{enroll}_{\bar{c}} - \underline{enroll}_{\bar{c}}, \quad \forall \bar{c}_{\bar{a}, b, \bar{r}}, pp \quad (2)$$

$$\sum_{r|\{c\}_{b, r, r} \neq \phi} \sum_a COHORT_{c(a, \bar{a}, b, r), pp - ttime_{\bar{c}} - dtime_{\bar{c}}} \geq \sum_a COHORT_{c(\bar{a}, a, b, r), pp}, \quad \forall \bar{a}, b, r | \{c\}_{b, r, r} \neq \phi, pp \quad (3)$$

$$\sum_{\bar{r} = \text{"flying" or "expert"}} \sum_{\{\bar{c}\}_{\bar{a}, b, \bar{r}}} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} \geq ratio_b * 2 * \sum_{\bar{s}} helos_{\bar{a}, \bar{s}, pp}, \quad \forall \bar{a}, b, pp \quad (4)$$

$$2 + \sum_{\{\bar{c}\}_{\bar{a}, b, \bar{r}} = \text{"cadre"}} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} \leq \overline{billets}_b, \quad \forall b, pp \quad (5)$$

$$\sum_{\bar{r}} \sum_{\{\bar{c}\}_{\bar{a}, \bar{r}, pilot}} \sum_{\rho = pp - ttime_{\bar{c}} + 1}^{pp} COHORT_{\bar{c}, \rho} \leq stu2brd * helos_{\bar{a}, \text{"HC3"}, pp}, \quad \forall \bar{a}, pp \quad (6)$$

$$\sum_{\bar{r} = \text{"expert"}} \sum_{\{\bar{c}\}_{\bar{a}, \bar{r}, pilot}} \sum_{\rho = pp - ttime_{\bar{c}} + 1}^{pp} COHORT_{\bar{c}, \rho} \leq stu2instr * \left[ 2 + \sum_{\bar{r} = \text{"cadre" or "instr"}} \sum_{\{\bar{c}\}_{\bar{a}, \bar{r}, pilot}} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} \right], \quad \forall \bar{a}, pp \quad (7)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \bar{r}, pilot}} \sum_{\rho = pp - ttime_{\bar{c}} + 1}^{pp} \frac{sflthrs_{\bar{c}}}{ttime_{\bar{c}}} * COHORT_{\bar{c}, \rho} \leq \frac{\overline{utilrate}_{\bar{a}} * helos_{\bar{a}, \text{"HC3"}, pp}}{12}, \quad \forall \bar{a}, pp \quad (8)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = pp - ttime_{\bar{c}} + 1}^{pp} \frac{sflthrs_{\bar{c}} * COHORT_{\bar{c}, \rho}}{ttime_{\bar{c}}} \leq \overline{mlogtime} * \left[ 2 + \sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} \right], \quad \forall \bar{a}, pp \quad (9)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = \underline{pp}_{qp} - ttime_{\bar{c}} + 1}^{\overline{pp}_{qp}} \min \left[ \overline{pp}_{qp} - \underline{pp}_{qp} + 1, \overline{pp}_{qp} - \rho + 1, ttime_{\bar{c}}, \rho + ttime_{\bar{c}} - 1 - \underline{pp}_{qp} + 1 \right] * \frac{sflthrs_{\bar{c}}}{ttime_{\bar{c}}} * COHORT_{\bar{c}, \rho} \leq \overline{aflthrs}_{\bar{a}, qp}, \quad \forall \bar{a}, qp \quad (10)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = \underline{pp}_{qp} - ttime_{\bar{c}} + 1}^{\overline{pp}_{qp}} \min \left[ \overline{pp}_{qp} - \underline{pp}_{qp} + 1, \overline{pp}_{qp} - \rho + 1, ttime_{\bar{c}}, \rho + ttime_{\bar{c}} - 1 - \underline{pp}_{qp} + 1 \right] * \frac{sflthrs_{\bar{c}}}{ttime_{\bar{c}}} * COHORT_{\bar{c}, \rho} \leq \overline{qlogtime} * \left[ 2 + \sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = \underline{pp}_{qp} - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{\overline{pp}_{qp} - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} \right], \quad \forall \bar{a}, qp \quad (11)$$

$$2 + \sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}}} COHORT_{\bar{c}, \rho} = \overline{instructors}, \quad \forall pp \quad (12)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 12 + 1}^{pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 12 + 12} COHORT_{\bar{c}, \rho} = 6, \quad \forall pp \quad (13)$$

$$\sum_{\{\bar{c}\}_{\bar{a}, \text{pilot}^*} \neq \emptyset} \sum_{\rho = pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 1}^{pp - ttime_{\bar{c}} - dtime_{\bar{c}} + 12} COHORT_{\bar{c}, \rho} = 6, \quad \forall pp \quad (14)$$

$$START_{\bar{c}, pp} \in \{0, 1\}, \quad \forall \bar{c}, pp \quad (15)$$

$$EMPTY_{\bar{c}, pp} \geq 0, \quad \forall \bar{c}, pp \quad (16)$$

$$COHORT_{c, pp} = \text{Integer} \geq 0, \quad \forall c, pp \quad (17)$$

$$COHORT_{c, ph} = roster_{c, ph}, \quad \forall c, ph \quad (18)$$

## B. VERBAL FORMULATION

The labeled model components express the following notions:

- (1),(2) If a training cycle starts in planning period  $pp$ , then the number of crewmen in that cohort will be between the stated minimum and maximum; otherwise, there will be nobody in the cohort.
- (3) If a cohort commences career cycle  $c$  with role  $r$  at the start of period  $pp$ , and if this cycle requires veterans immediately completing some prior cycle (or cycles), then each preceding cycle  $c$  with admissible preceding roles  $r$  must have commenced in sufficient numbers at the start of  $pp - ttime_c - dtime_c$  and finished at the end of  $pp-1$ .
- (4) The number of each aircraft  $\tilde{a}$  (excluding training aircraft) and its crew seat ratio for billet  $b$  induces demand for cohorts with career cycles including period  $pp$  as a duty period in a flying role. Each aircraft has two pilot and two aircrewmen seats.
- (5) The number of crewmen of billet type  $b$ , in all of the HC squadrons, must never exceed the total number of billets allotted to the squadrons.
- (6),(7) The number of student pilots that can be trained in aircraft type  $\tilde{a}$  during period  $pp$  is limited by the number of training aircraft and by the number of pilot instructors at HC-3. The executive officer (XO) and the commanding officer (CO) of HC3 also serve as pilot instructors.
- (8),(9) The number of hours flown by student pilots in aircraft type  $\tilde{a}$  during period  $pp$  is limited by the maximum utilization rate for the aircraft, and by the hours pilot instructors can fly.
- (10),(11) The number of hours flown by student pilots in aircraft type  $\tilde{a}$  during quarter  $qp$  is limited by budgeted flight hours and by the maximum hours pilot instructors can fly.
- (12) There is a billet limit on the number of pilot instructors at HC-3.
- (13),(14) There must be one XO and one CO for each squadron in each planning period  $pp$ . The duty tour portion of a cycle filling the 'XO/CO' role is 15 months as XO plus 15 months as CO.
- (15) The decision variable to initiate each cohort is binary.
- (16),(17) The size of each cohort and number of empty seats in each cohort are represented by nonnegative decision variables. Cohort enrollments are integer.

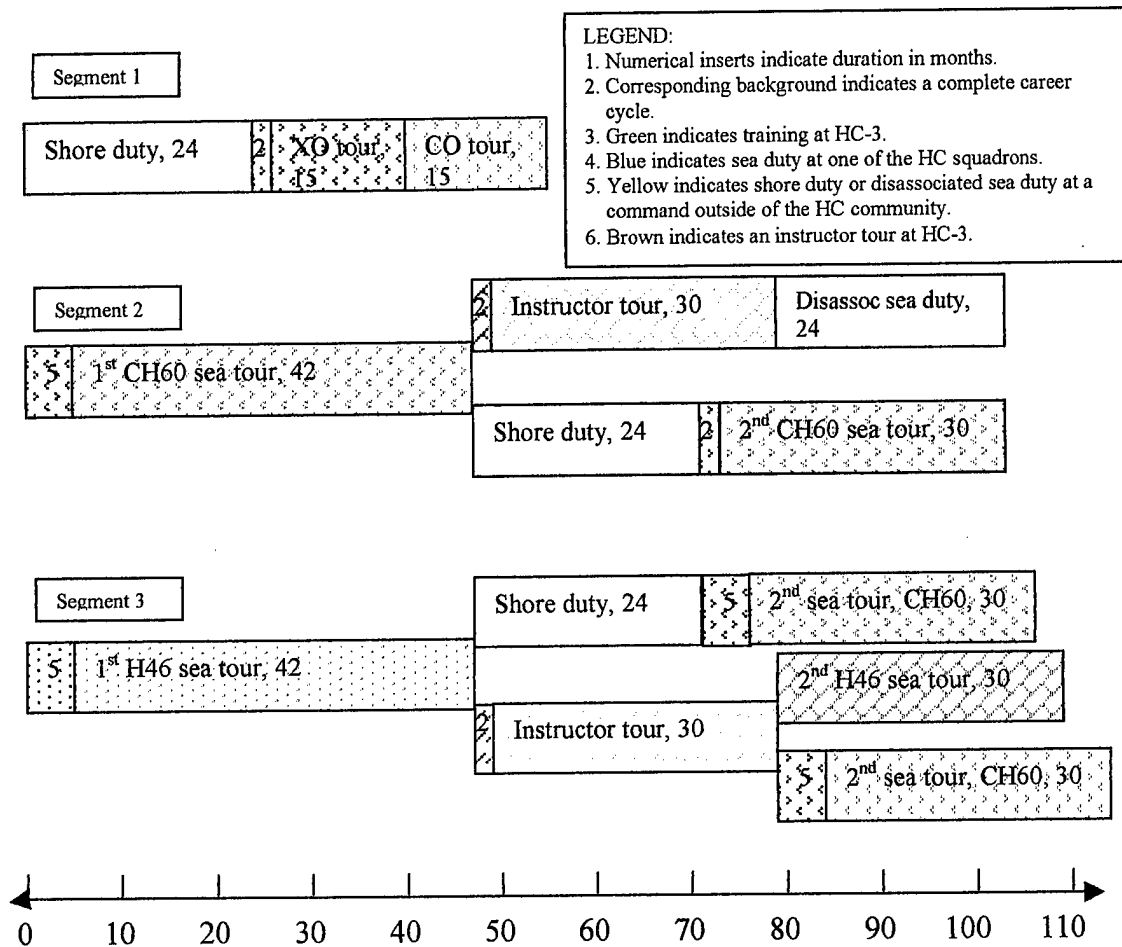
(18) If the first planning period is  $pp$ , then all career cycles just completed or still in session at that time must be provided as initial conditions (i.e., data is required for career cycles that started during  $ph = -ttime_c - dtime_c + 1, \dots, pp - 1$ ).

### C. IMPLEMENTATION

A crewman's career is characterized herein by a succession of *career cycles*.

Each career cycle begins with a training syllabus to become qualified for a follow-on tour of duty at an HC squadron, and ends with the expiration of that duty tour. Shore duty or disassociated sea duty at a command outside of the HC community also constitutes a career cycle. For example, an H-46D pilot's initial sea duty career cycle begins with training at HC-3 followed by sea duty at an HC squadron. Next, that pilot would start a second career cycle on either shore duty at a command other than an HC squadron, or shore duty as an instructor at HC-3. In the latter case, the prospective instructor would start the second career cycle with either pilot instructor training in the H-46D, or aircraft and instructor training in the CH-60S, followed by 30 months of instructing students in that aircraft. Career cycles last between 24 and 47 months and are pre-determined by the Bureau of Personnel (BUPERS) according to billet type and crew qualification.

[BUPERS, 1999] Figure 3 illustrates a segment of three possible career paths.



**Figure 3. Career Cycles**

This figure illustrates how career cycles integrate to form a segment of the career of a crewman. For example, from segment 2 of this figure, a CH60S pilot begins his first career cycle with five months training at HC-3 followed by 42 months in his first sea tour at an HC squadron, completing his first career cycle. Next, he'll start his second career cycle either on shore duty, or transfer to HC-3 and start the instructor under training syllabus, for two months, followed by 30 months as an instructor at HC-3, completing his second career cycle.

Crewmen starting a particular career cycle in a given time period are referred to herein as a *cohort*, with the number of crewmen in a *cohort* represented as the value of the *COHORT* variable. The size of a *cohort* is determined by the minimum and maximum training enrollment for that particular type of crewmen. Unused capacity in a *cohort* is recorded in CTM by the *EMPTY* variable.

Decisions concerning when to start a *cohort* are governed by underlying time intervals associated with scheduling training activities and budgeting limits placed on aircraft use. Time interval lengths adopted herein for “*data elements*” and “*VARIABLES*” adhere as closely as possible to the practices followed at HC-3 with respect to flight hour budgeting, syllabus management, and crewmen and aircraft flight hour management. (Table 5)

<i>data</i> or <i>VARIABLE</i>	Definition	Units	Time Precision
<i>ttime</i>	Training time	months	monthly
<i>dtime</i>	Duty time	months	monthly
<i>sflthrs</i>	Syllabus flight hours	flight hours	hours
<i>helos</i>	Number of helicopters	unit monthly	monthly
<i>utilrate</i>	Helo utilization rate	hours per quarter	quarterly
<i>aflthrs</i>	Aircraft flight hours	hours per quarter	quarterly
<i>logtime</i>	Instructor flight time	hours per quarter	quarterly
<i>COHORT</i>	Set of crewmen	crewmen	monthly
<i>EMPTY</i>	Unused capacity	crewmen	monthly

**Table 5. Data Elements and Variables**

This table shows *data elements* and *VARIABLES* defined by units and the precision of time that each data element and variable is measured. For example, *aflthrs* represents the maximum number of flight hours budgeted quarterly to HC-3 for H-46D aircraft or CH-60S aircraft.

In order to plan the future training program at HC-3 one must locate crewmen already engaged in preceding career cycles. This is because the ongoing process of detailing crewmen requires that certain career cycles precede or follow other career cycles to satisfy Navy policy and requirements for prior experience. For example, to be eligible to instruct at HC-3, a crewman must come directly from sea duty with an HC squadron. New crewmen who have not had a prior career cycle (also known as Nuggets) are received directly from officer flight school or an enlisted rating school.



Flight hours at HC-3 are limited by budget constraints and by the total hours that aircraft and instructors can fly per time period. Student demand for flight hours is forecasted by dividing the flight hours required for a complete syllabus by the expected training time in months of that syllabus (i.e. a uniform rate of flying is assumed throughout training).

#### 1. Data Element Implementation

$\overline{enroll}_c, \overline{enroll}_c$ : Class sizes must be constrained due to limited aircraft and instructor availability. The “enrollment” data elements show the maximum and the minimum class size for any particular cohort.

$ttime_c$ : Training duration varies by cohort type. The “training time” data element indicates the standard number of months it takes for any cohort to complete training.

$dtime_c$ : Career cycle lengths vary by type. The “duty time” data element shows the standard number of months that each career cycle lasts.

$sflthrs_c$ : Training flight hours vary by cohort type. The “syllabus flight hours” data element indicates the standard number of training flight hours required to complete training for each cohort.

$helos_{\bar{a},s,pp}$ : The “helos” data element expresses the number of CH-60S and H-46D aircraft that each HC fleet squadron is expected to hold in its inventory in any month during the planning horizon (e.g. Table 6).

	<u>HC-6</u>		<u>HC-8</u>		<u>HC-11</u>	
	H46	CH60	H46	CH60	H46	CH60
2003may	2	14	14	0	18	0
2003jun	0	16	14	0	18	0
2003jul	0	16	14	2	18	0
2003aug	0	16	12	4	18	0
2003sep	0	16	10	6	18	0
2003oct	0	16	10	6	18	3
2003nov	0	16	10	6	18	5
2003dec	0	16	10	6	16	7
2004jan	0	16	10	6	15	8
2004feb	0	16	8	8	15	8
2004mar	0	16	8	8	14	9

**Table 6. Squadron Aircraft Populations**

This is a portion of the table that shows the number of H-46D and CH-60S aircraft that each squadron is expected to hold for each month in the planning horizon. For example, in May 2003, HC-6 should have 2 H-46D aircraft and 14 CH-60S aircraft.

$ratio_b$  : The “ratio” data element represents the minimum manning requirement for pilots and aircrewmembers in the HC fleet squadrons in terms of crewmembers per aircraft.

$\overline{billets}_b$  : There is a fixed number of billet assignments for crewmembers in the HC fleet squadrons. The “billets” data element is an upper bound to the aggregate number of pilot billets and aircrew billets in the HC fleet squadrons.

$stu2brd, stu2instr$  : Student capacity at HC-3 is limited by available training aircraft and instructors. The “student to bird” and “student to instructor” data elements represent the ratio limits on the number of student crewmembers enrolled at HC-3 in terms of aircraft and instructors, respectively.

$\overline{utilrate}_a$  : All aircraft have maximum flight hour limitations for differing lengths of time. The “utility rate” data element limits the maximum aircraft flight hours per calendar year.

$\overline{aflthrs}_{a,qp}$  : HC-3 must budget flight time for flight training in any time period. The “aircraft type flight hours” data element limits the flight hours in each quarter of

each calendar year by aircraft type. CTM does not observe the use of flight hours for maintenance and missions other than training.

$\overline{mlogtime}$ ,  $\overline{qlogtime}$ : Pilot and aircrew instructors are limited by the number of hours that they can fly in any particular time period. The “monthly logtime” and “quarterly logtime” data elements limit the number of hours these crewmen may fly in any month or quarter of the planning periods.

$\overline{instructors}$ : This data element represents the limit on the total number of pilot instructors, excluding the XO and CO, allowed on staff at HC-3.

$roster_{c,p}$ : The “roster” data element expresses the historical record of all existing pilot and aircrew cohorts from January 1995, through December 1998. These individuals enter the planning portion of the model when their existing duty tour ends.

#### **D. CAREER CYCLE AND TIME PERIOD IMPLEMENTATION**

Career cycles are indexed according to four dimensions that each career cycle exhibits. The first is the aircraft qualification a crewman possesses before training at HC-3. These are H-46D, CH-60S, or Nugget, which designates a crewman who has not yet had a fleet tour. The second describes the aircraft qualification possessed upon graduation from training at HC-3. These are H-46D or CH-60S. The third designates the billet filled at the next duty tour, either a pilot billet or an aircrewman billet. The fourth enumerates seven different roles that a crewman may fill while on a duty tour. These are cadre, flying, instructor, executive and commanding officer, expert, shore duty, and disassociated sea duty. The roles shore duty and disassociated sea duty are not associated with training at HC-3. A “cadre” crewman is trained as a CH-60S instructor before the

beginning of the transition, specifically to train the first classes of CH-60S crewmen. "Flying" roles describe junior officers and aircrewmen who are fleet crewmen at HC squadrons, junior officers who are not department heads, and executive officers or commanding officers. "Instructor" and "executive and commanding officer" roles are self-explanatory. The "expert" role describes a small group of pilots who were trained before the beginning of the transition period and are not at HC-3. They are used to fill manning requirements for the initial few CH-60S aircraft entering the fleet. "Shore duty" indicates crewmen who are not at HC-3, nor any of the other HC squadrons. The standard length of shore duty is varied from 23 to 25 months to give the model flexibility in scheduling crewmen to fit training and billet requirements. This mimics Navy detailers dealing with the same problems. Lastly, "disassociated sea duty" describes crewmen who are at sea but not attached to any of the HC Squadrons. Disassociated sea duty lengths are also varied for 23 to 25 months.

A subset of the roles describes crewmen who are flying. These are cadre, flying, instructor, executive and commanding officer, and expert.

Because a crewman is not qualified at just any stage of his career to fill all billets and roles, those pairs of career cycles that are admissible are linked together depicting which career cycles may precede or follow other career cycles. For example, a CH-60S nugget who has completed his first sea duty tour at an HC Squadron is allowed to go to shore duty or train to be a CH-60S instructor, but is not allowed to go to sea duty as a department head or executive officer.

Periods of time are indexed with monthly precision. These periods run from January 1995 through December 2010. January 1995 through December 1998 are historical periods, and planning periods extend from January 1999 through December 2010. In addition, quarterly planning periods index aggregate quarters throughout this latter planning horizon.

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### **III. DATA COLLECTION**

#### **A. THE COLLECTION PROCESS**

Data has been collected for this thesis from many sources including the H-60R/S FIT, NAS North Island CA [FIT, 1999]; the Multi-Mission Helicopter Program Office (PMA-299), NAS Patuxent River MD [NAVAIR, 1998a]; HC-2, NAS Norfolk VA [HC-2, 1999]; HC-3, NAS North Island CA [HC-3, 1999]; HC-5, Andersen Air Force Base, Guam [HC-5, 1999]; HC-6, NAS Norfolk VA [HC-6,1999]; HC-8, NAS Norfolk VA [HC-8,1999]; HC-11, NAS North Island CA [HC-11,1999]; the Naval Personnel Command (NPC) (PERS-40, PERS-43, PERS-45), Millington TN [BUPERS,1999]; and Manpower (N122E1C), NPC [BUPERS, 1999]. The data was collected via telephone calls, facsimile, email, and postal mail.

Surprisingly, the most significant data problem has been determining rudimentary career histories of crewmen currently located at the HC squadrons, including HC-3. The required data for an individual crewman is the type of duty tour and the time it began. This is needed to forecast when the tour of duty ends, and thus, plan a follow-on tour. Apparently, none of the offices affiliated with the Naval Personnel Command (NPC) has ever maintained a single, unified data base, spread sheet, or file that can be used as a single-source reference for details such as how many H-46 crewmen are trained each month, when they arrive at their sea duty command, and how many arrive at each command during any given time period.

Data collection has been hampered because much of the data is contained in documents such as Enlisted Data Verification Records (EDVR) and Officer Distribution

Control Reports (ODCR) that contain sensitive information such as social security numbers, and thus fall under privacy act regulations. Instead, this information had to be manually distilled by officer and enlisted detailers from EDVRs, ODCRs, and individual files. The data was then compiled into a single readable file, listing name, rank, designator, sea or shore duty, command, report date, and projected rotation date. This data was further transposed into the historical table described in Chapter II, Section B for use in CTM.

Given the rudimentary questions addressed in this thesis, questions that doubtless recur over time, it seems advisable that the HC community commit itself to at least a single data base to track and readily describe key facets of the HC community over time.

## **B. WHERE THE DATA WAS COLLECTED**

$\overline{enroll}_c, enroll_c$ : Feasible class sizes were determined through telephone conversations with the training officers and enlisted personnel of the HC-3 training department [HC-3, 1999]. All class sizes were given a minimum value of zero and a maximum value of six except for CH-60S nuggets and flyers which were given maximum class sizes of 12.

$time_c$ : The training duration of each H-46D cohort was obtained from the HC-3 Master Curriculum Guide [MCG, 1997]. CH-60S cohort training durations were obtained from the H-60R/S FIT by email. Each training duration was truncated to the nearest whole month.

$dtime_c$ : Career cycle lengths were approximated and confirmed through telephone conversations with enlisted and officer detailers at NPC [BUPERS, 1999].



$sflthrs_{\varepsilon}$  : The required syllabus flight hours for each H-46D cohort was obtained from the HC-3 Master Curriculum Guide. CH-60S cohort syllabus flight hour requirements were obtained from the H-60R/S FIT [FIT, 1999].

$helos_{\bar{a},s,pp}$  : This data, which express the number of CH-60S and H-46D aircraft that each HC fleet squadron is expected to hold in inventory in any month during the planning period, was collected from the H-60R/S FIT [FIT, 1999].

$ratio_b$  : The crew seat ratio, equal to 1.5 for pilots and aircrewmembers, was obtained from the H-60R/S FIT [FIT, 1999]. This scalar has been the standard in the H-46D community and should continue to be the standard in the CH-60S community.

$\overline{billets}_b$  : The number of available HC pilot and aircrewmembers billets, equal to 315 and 318, respectively, was extracted from data from BUPERS N122E1C [BUPERS, 1999].

$stu2brd, stu2instr$  : The respective ratios 2.42 and 1.14 were deduced from data from the training department at HC-3 [HC-3, 1999].

$\overline{utilrate}_{\bar{a}}$  : These data are NATOPS [NATOPS, 1996] limitations with maintenance availability rates already factored into their valuations. These limits are set to 404 flight hours per H-46D per year and 650 flight hours per CH-60S per year.

$\overline{aflthrs}_{\bar{a},qp}$  : Quarterly flight hours budget data was estimated by and retrieved from the HC-3 operations office [HC-3, 1999] via telephone call. CTM does not observe the use of flight hours for maintenance and missions other than training.

$\overline{mlogtime}$ ,  $\overline{qlogtime}$ : These crewmen flight time limitations found in OPNAVINST 3710.7R [OPNAV, 1999] are set herein at 100 flight hours per month and 265 flight hours per quarter, respectively.

$\overline{instructors}$  : The 30 instructors are validated by the HC-3 Training Department [HC-3, 1999].

$\overline{roster}_{c,p}$  : The roster data, which expresses the historical record of all existing pilot and aircrew cohorts from January 1995 through December 1998, was retrieved through phone calls and facsimiles with enlisted and officer detailers and all six worldwide HC squadrons referenced in this thesis [BUPERS, 1999].

#### **IV. CREWMEN TRAINING MODEL RESULTS**

This chapter presents the results of implementing CTM for basic training at HC-3 and the effect of varying the number of instructors at HC-3.

##### **A. GENERAL ALGEBRAIC MODELING SYSTEM (GAMS) IMPLEMENTATION**

CTM is implemented in GAMS (Release 2.25) [GAMS, 1997] using the CPLEX 6.5 solver, a commercial optimization software package developed by the ILOG CPLEX Division. [ILOG, 1999] Using a fifteen-year planning horizon with monthly resolution, GAMS generates 9,601 equations, 17,823 variables, and 347,161 non-zero elements. The relative integrality gap (the maximum deviation from optimality) is 6.6 percent. CTM finds an all-integer solution after 9,882 iterations in 14 minutes using a Pentium-II, 333 MHz personal computer with 192-megabytes of random access memory.

##### **B. HC-3 BASIC TRAINING STRUCTURE**

The basic training resources for CTM are described in Table 7. This basic training structure, although somewhat simplified, is currently in effect and is the planned basis for the transition from the H-46D to the CH-60S aircraft.

##### **C. BASELINE SOLUTION BY THE CREWMEN TRAINING MODEL**

The planning horizon starts in January 1999, the beginning of the first transition year. The historical table ends in December 1998. (Data for the historical table is available through April 1999, but has only been used through December 1998.) The historical data already suggests a shortage of HC pilots and aircrewmen. In addition, the current crewmen and executive officer and commanding officer of HC-2 are not placed in

the historical table because the intent is to model the transition from the H-46D to the CH-60S. The current airframe at HC-2 is the UH-3A and VH-3A Sea King. HC-2 is scheduled to receive its first CH-60S in December 2003.

Training Aircraft (H-46D and CH-60S)	14 Aircraft
H-46D Annual Utilization per Aircraft	404 Flight Hours
CH-60S Annual Utilization per Aircraft	650 Flight Hours
HC-3 Flight Hours Allowed per Quarter	1575 Flight Hours
Instructors (H-46D and CH-60S)	30 Instructors
Quarterly Maximum Instructor Flight Time	265 Flight Hours
Monthly Maximum Instructor Flight Time	100 Flight Hours
Student to Instructor Ratio	1.13
Student to Bird Ratio	2.42

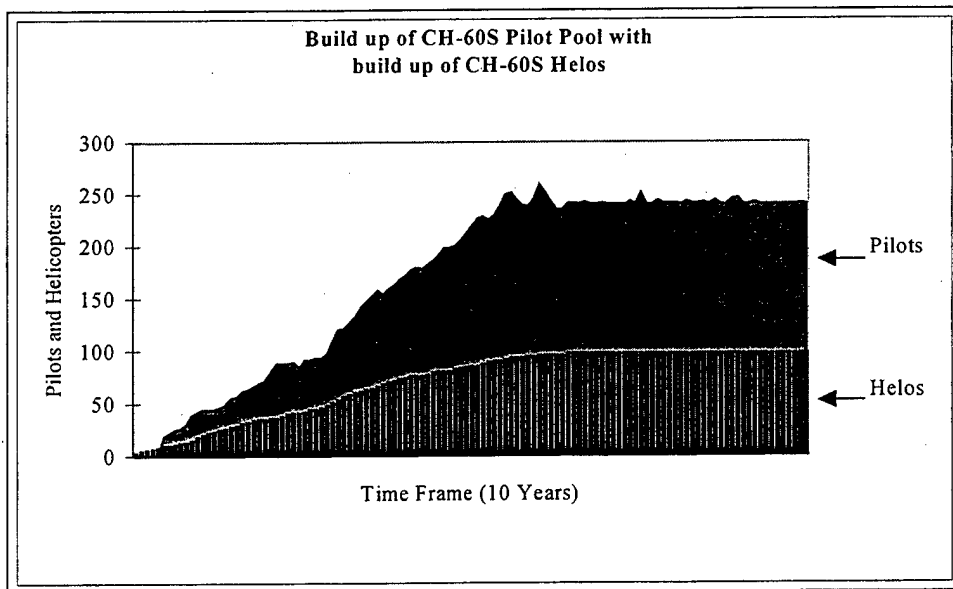
**Table 7. HC-3 Basic Training Resources**

This table shows the very basic training structure that exists at HC-3. The data presented in this table should remain constant throughout and after the transition. One notable exception is that the number of training aircraft at HC-3 will grow from 14 to 17 aircraft by the end of the transition period.

The model shows how to correct the deficiency in H-46D crewmen within the first transition year without violating any personnel or aircraft limitations at HC-3. It also begins training CH-60S crewmen during the first month of the transition in concert with the first CH-60S training aircraft deliveries to HC-3.

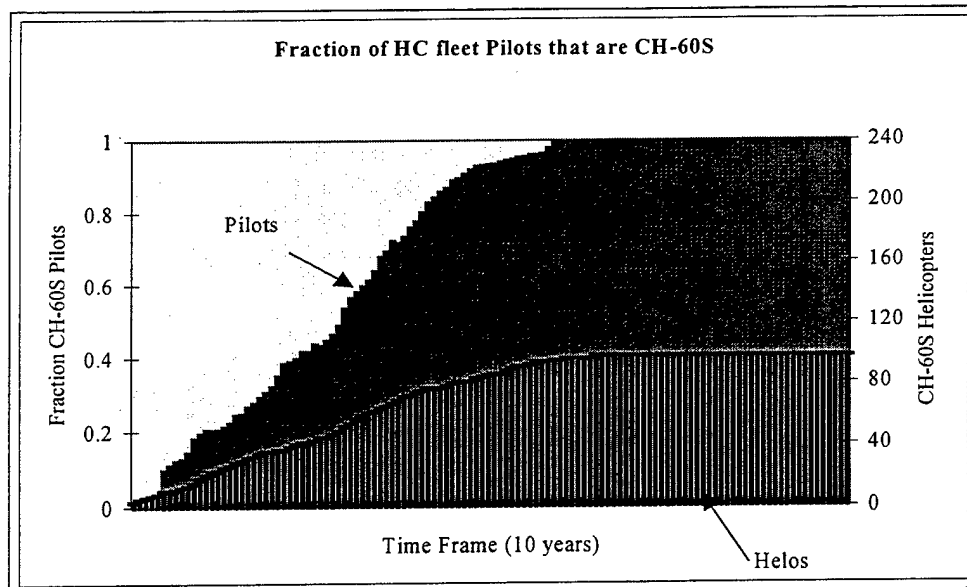
CTM delivers a training schedule with monthly precision. CTM averages about 5 pilots and 4 aircrewmen for the CH-60S aircraft, in addition to 4 pilots and 3 aircrewmen for the H-46D, to begin training each month during the first transition year. During the first five transition years, CTM averages 6.4 pilots and 4.5 aircrewmen for the CH-60S and 1.6 pilots and 0.6 aircrewmen for the H-46D. Through the year 2014, CTM averages 8.3 total pilots and 4.4 total aircrewmen to begin training each month. Of this, an average of 7.7 CH-60S pilots and 4.2 CH-60S aircrewmen begin training each month.

CTM forecasts and accommodates crewmen requirements, which are driven by aircraft deliveries and manning requirements. (Figures 4 and 5)



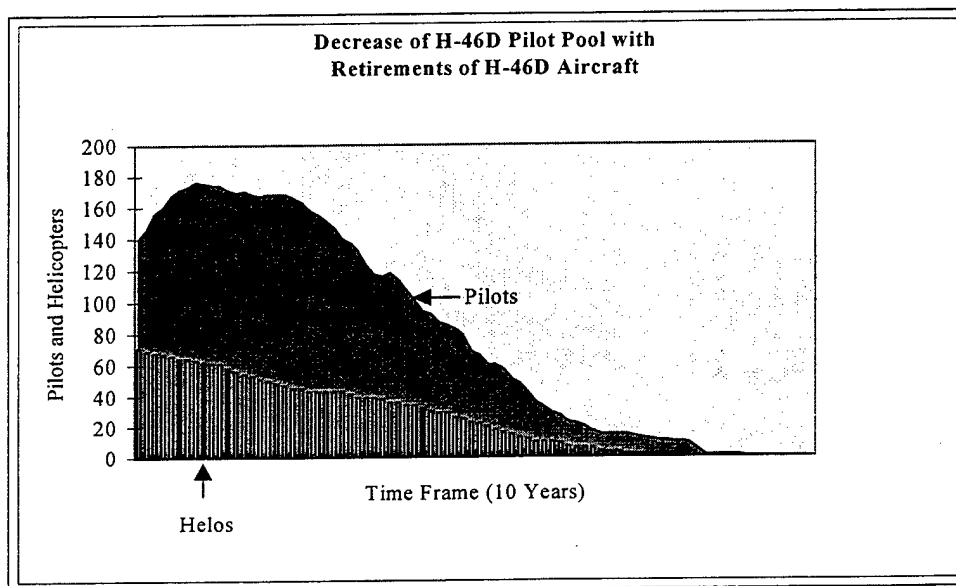
**Figure 4. Demonstration of CH-60S Pilot Training Requirements**

This figure shows the buildup of fleet CH-60S pilots with the progression of the distribution of CH-60S aircraft. Initial CH-60S aircraft deliveries go to HC-3 for training. This accounts for the early rise in CH-60S aircraft ahead of the CH-60S pilot population. As expected, the CH-60S pilot graph begins to level off just before completion of CH-60S deliveries. This indicates where the training of CH-60S pilots begins to slow and the number of CH-60S pilots entering the HC community roughly equals the number CH-60S pilots transferring to a new tour of duty. Most importantly, this graph demonstrates how aircraft deliveries and manning requirements drive the model.



**Figure 5. The Transition from H-46D to CH-60S Pilots in the HC Community**  
 This figure shows how the type of the pilots in the HC community changes from H-46D to CH-60S as CH-60S aircraft are introduced into the community. The lower area indicates the growing population of CH-60S aircraft on the right vertical scale. The background shows the growing CH-60S pilot population as a fraction of all fleet HC pilots on the left vertical scale.

CTM predicts decreasing crewmen requirements for the H-46D fleet. (Figure 6)



**Figure 6. H-46D Pilot Training**  
 This figure shows how the H-46D Pilot population decreases as H-46D aircraft are retired. As expected, CTM assures that there are H-46D crewmen left over when the last H-46D is retired.

Table 8 shows the 12 year annual training schedule, predicted by CTM and based on the May 1999 Sikorsky distribution schedule [FIT, 1999], for all cohorts grouped under billet and aircraft type.

Calendar Year	Transition Year	CH-60S Pilots	H-46D Pilots	CH-60S Aircrew	H-46D Aircrew	Total Pilots	Total Aircrew
1999	1	57	41	47	30	98	77
2000	2	57	31	73	0	88	73
2001	3	77	15	47	8	92	55
2002	4	90	2	41	5	92	46
2003	5	104	0	40	3	104	43
2004	6	100	0	80	0	100	80
2005	7	111	0	79	0	111	79
2006	8	104	0	48	0	104	54
2007	9	104	0	54	0	104	60
2008	10	94	0	30	0	94	30
2009	11	105	0	72	0	105	72
2010	12	112	0	78	0	112	78

**Table 8. Recommended Annual Training Schedule**

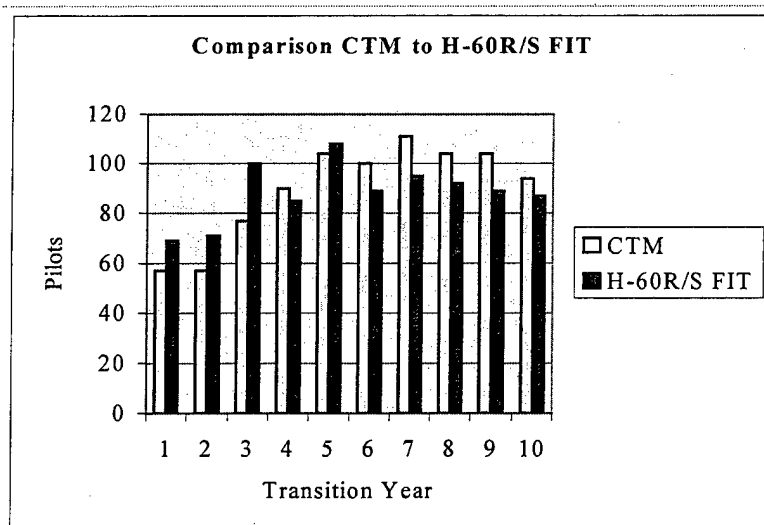
This table presents the recommended annual training schedule of all crewmen grouped by aircraft and billet type based on the current Sikorsky CH-60S distribution schedule [FIT, 1999].

#### **D. THE H-60R/S FIT MODEL**

The H-60R/S FIT has developed a spreadsheet model similar in purpose to CTM. In contrast to this spreadsheet, CTM is a mathematical optimization model and utilizes instructor and training aircraft availability, instructor training, training aircraft readiness, duty tour descriptions and calculations, and the availability of crewmen to begin training at HC-3. CTM recognizes that there is a finite population of individual pilots and aircrewmembers that must be scheduled synchronously over the entire planning horizon, as well as over each individual career path.

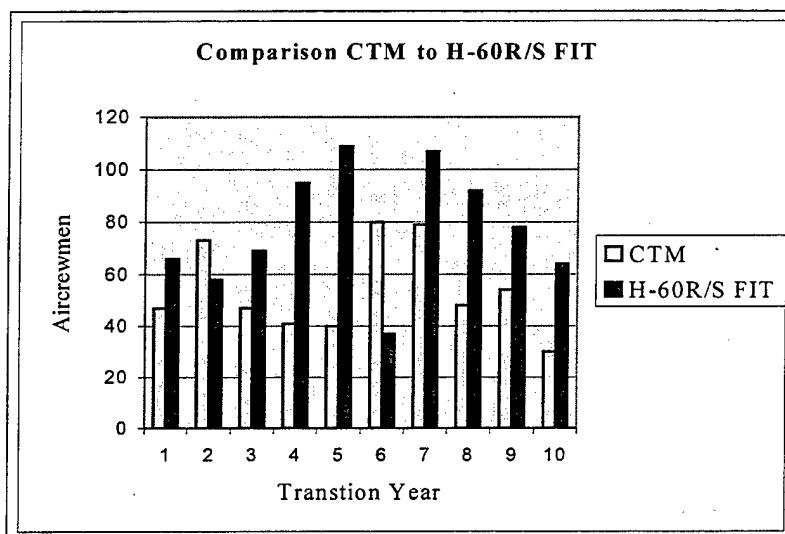
The models have similar crew seat manning ratios, duty tour lengths, and the same CH-60S distribution schedule. The H-60R/S FIT plans to use CTM to validate their spreadsheet model.

Figures 7 and 8 compare annual training schedules produced by the H-60R/S FIT spreadsheet and CTM.



**Figure 7. CH-60S Pilot Training Comparison**

This figure shows a comparison of CTM and the H-60R/S FIT spreadsheet detailing the number of CH-60S pilots that should be trained annually. CTM, the optimization model, and the H-60R/S spreadsheet model closely agree on the annual training requirements for CH-60S pilots.



**Figure 8. CH-60S Aircrewmen Training Comparison**

This figure shows a comparison of CTM and the H-60R/S FIT spreadsheet detailing the number of CH-60S aircrewmen that should be trained annually. CTM suggests training fewer aircrewmen in all but two of the first ten years after the beginning of the transition. This variance is conjectured to be due to differences in aircrewmen training requirements between the models.



Both models suggest very similar pilot training schedules. However, the two models vary widely in the numbers of suggested aircrewmen. The author attributes the difference to the presumption that the H-60R/S FIT spreadsheet treats general aircrewmen training requirements differently than CTM. CTM optimally trains just enough aircrewmen to meet crew seat minimums and billet limitations.

#### **E. VARYING THE DURATION OF SHORE DUTY**

The standard duration of shore duty and disassociated sea duty for Navy pilots is 24 months. Chapter II Section D introduces these two duty types, which are allowed to vary from 23 to 25 months. This is a relaxation of Navy policy, of the Navy's problem, and of the model. This relaxation simulates the Navy detailer practice of fitting pilots to roles. Detailers may vary the duration of squadron duty tours as well. In our case, a variation of at most a month ensures there are available pilots to rotate to a new duty tour every month. The relaxation helps fill the monthly requirements for newly-trained pilots during the transition.

If shore duty and disassociated sea duty are restricted to exactly 24 months, CTM cannot rotate sufficient numbers of qualified and experienced pilots to start training to immediately fill all executive and commanding officer requirements and instructor pilot requirements. This is because the HC community and the model are operating with a deficit of pilots prior to the beginning of the transition. Varying duty tour lengths is a necessary part of the detailing process.

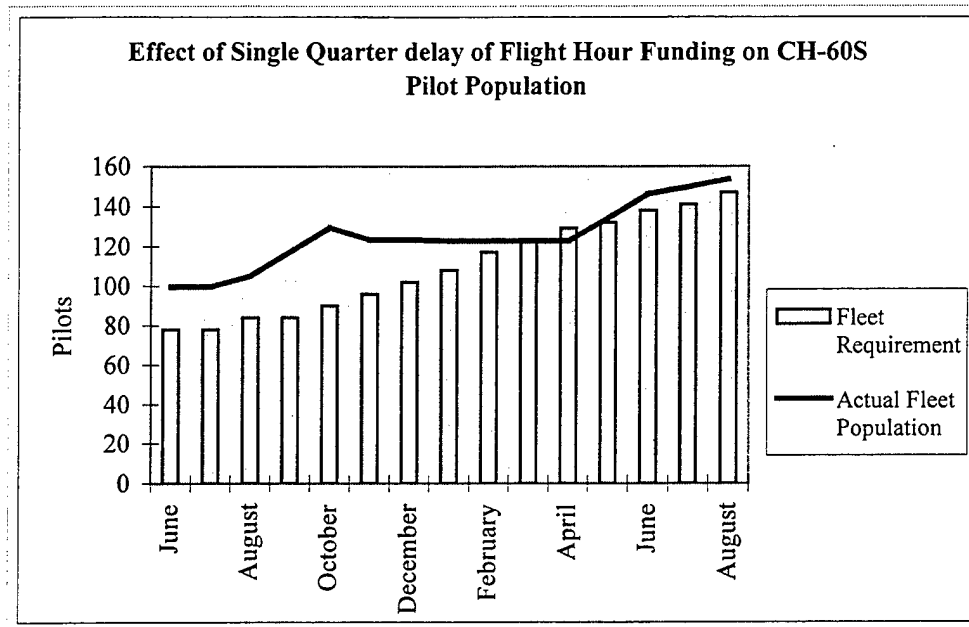
## **F. WHAT WOULD HAPPEN IF ...?**

What would happen if there is some event that delays training at HC-3?

Suppose there is a delay of production at Sikorsky, or there are problems distributing the aircraft. This would lighten the training load at HC-3 and not stress the training program at any time since there would not be as large a demand for qualified crewmen.

Conversely, suppose the defense budget is delayed by one quarter. For instance, from October through December of 2001, flight hour funding is directed away from HC-3 to fund the HC fleet squadrons, but the distribution of CH-60S aircraft to the fleet squadrons continues as already scheduled.

The immediate effect, theoretically, would stop flight training at HC-3 completely for three months. When funding to HC-3 is renewed, the after-effects would include a backlog of students at HC-3, and training requirements would exceed the capability of the instructor staff. The long-term effect in the fleet would be a deficit of qualified CH-60S pilots to man available CH-60S aircraft at the fleet squadrons HC-5 and HC-6. Figure 9 illustrates the long-term effect of this scenario on the fleet population of CH-60S pilots.



**Figure 9. Effect of Flight Hour Funding Delay**

This figure demonstrates the effect of losing flight hour funding from October through December of the third year of the transition. During April and May of the fourth transition year there would be a deficit in the required number of fleet CH-60S pilots.

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## V. CONCLUSIONS AND RECOMMENDATIONS

Currently, HC-3 has 14 H-46D training aircraft, 30 pilot instructors and 14 aircrew instructors, and expects to receive funds for approximately 1,575 flight training hours per quarter. During the transition, they will receive 17 CH-60S training aircraft, increasing their overall squadron aircraft population by three. They will also have to maintain the current population of the pilot and aircrew instructors, with appropriate aircraft qualifications commensurate with the ratio of H-46D and CH-60S aircraft.

Given the fluid schedule of CH-60S aircraft, the Crewmen Training Model indicates there will be sufficient training aircraft during the transition. Additionally, a planned budget of 1,575 flight training hours per quarter is adequate. CTM indicates the staff of instructors at HC-3 is not large enough, if during the first year of the transition, the current deficiency of H-46D crewmen is to be corrected. The model indicates that there should not be any other resource shortfalls during the planned transition.

This thesis shows a feasible training schedule for HC pilots and aircrewmen can be achieved that satisfies H-46D and CH-60S manning requirements and works within the operating and training structure at HC-3. There are three recommendations:

1. HC-3 maintain its current training and operating structure.
2. H-60R/S FIT maintain its planned operation and training structure for HC-3.
3. H-60R/S FIT use its spreadsheet-scheduling model in its current form.

The H-60R/S FIT should be careful to recognize that models can never completely emulate systems or processes but only closely approximate them. Time permitting, any model should be closely dissected to make sure that it is performing as intended. Also, to gain the proper insights, the conclusions drawn from the results of a model should be carefully examined.

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